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Testing of a Soil-Steel Structure With a Relieving Slab

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Abstract

The report records data from a live load test on a soil-steel structure with a relieving slab. The structure, located in Thunder Bay, had an elliptical conduit with a span of 8.76 m and a rise of 4.95 m. The maximum depth of cover was 1.65 m. Response of the structure was monitored through strain gauges on the metallic shell, and recorded data consist of live load thrusts and moments computed from measured strains. By comparison with similar test data of a similar structure with smaller span and rise, it is shown that the relieving slab has the effect of considerably reducing live load effects in the conduit wall.

Key Words Bridge test, Live load response, relieving slab, soil-steel structures

Comments

Distribution Unrestricted, MTC HO + regions, selected structural and geotechnical engineers.

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1/ INTRODUCTION

One method of reducing live load effects in soil-steel structures with shallow depths of cover is to provide a reinforced concrete slab above the conduit. This slab, known as the relieving slab, helps to distribute concentrated live loads over a greater area than would be possible if the slab was not there. It seems axiomatic that the relieving slab would reduce live load thrust and moment in the conduit wall. Some theoretical work has been done to account for this reduction, but the literature lacked test data to confirm any hypothesis. It should be noted that a soil-steel structure with a relieving slab has been tested before [4] but measured responses did not include strains of the conduit wall from which thrust and moments could be obtained.

A soil-steel structure with a relieving slab was load tested, and strains in the conduit wall measured. The purpose of this report is to record the test data. Conclusions drawn from the test data are discussed elsewhere [3].

2/ DETAILS OF THE STRUCTURE

The structure, called the McIntyre River soil-steel structure, is located in the city of Thunder Bay, Ontario, Canada. The conduit is elliptical with a span of 8.76 m and a rise of 4.95 m. At the embankment level, the structure is provided with a reinforced concrete relieving slab, as shown in Figure 1. The slab is 0.3 m thick, and measures 11.30 m x 8.76 m in plan. The reinforcement is provided near the bottom face and for most of the area of the slab, consists of 19 mm bars @ 0.46 m in the direction of traffic, and 19 mm bars @ 0.28 m in the perpendicular direction. The depth of cover under the roadway, including the relieving slab, ranges between 1.49 m and 1.65 m. The conduit walls consist of 5.54 mm thick steel plates of 152 x 51 mm corrugation profile.

The structure, which is owned by the City of Thunder Bay, was designed by Westeel-Roscoe Limited and is identified by the manufacturers as an elliptical K-D steel pipe. It was constructed in 1973. Little information is available about the backfill except that it comprised well compacted granular soil.

3/ INSTRUMENTATION AND TESTING VEHICLES

Thrusts and moments in conduit walls due to live loads were measured by means of temperature-compensated uniaxial electrical resistance gauges installed on the inside of the pipe. Only one section (identified in Figure 1) was instrumented. There were 11 stations around the instrumented section. Locations of these stations are shown in Figure 2. At each station, three gauges were installed after grinding the plate to smooth white metal. Locations of gauges at a typical station are also shown in Figure 2. A previously calibrated template was used to mark the positions of the three gauges. Responses from the strain-gauges were recorded by a computer-based data acquisition system which is described in Reference 1.

The live load was applied by means of two testing vehicles whose weights can be regulated by concrete blocks, each of which weighs about 1 tonne. For various load levels, the blocks were so placed on the trucks that the rear tandem axles of the vehicles carried most of the weight. Dimensions and weights of the two vehicles are shown in Figure 3. Tests with vehicle number one were carried out by loading it at three different levels. The second vehicle was used with only one level of loading.

During tests with a single vehicle, test vehicle number one travelled along four different longitudinal lines; for the test with two vehicles, the two testing vehicles travelled along one set of longitudinal lines. The transverse positions of these longitudinal lines are show in Figure 4. Along each longitudinal line, the vehicle(s) were stopped at seven different positions and gauge readings recorded. These positions are identified in Figure 5.

4/ MEASURED STATIC LOAD RESPONSES

Live load thrusts and moments in conduit walls at a station were computed from measured strains at the crest and valley of the corrugations. The gauge at the neutral axis of the corrugation profile was used to check that the variation between the crest and valley strains was linear.

The modulus of elasticity of steel was assumed to be 2.07×10^5 MPa. The conduit wall is made up of 5.44 mm thick plates. The moment of inertia of this plate was taken to be 2080 mm^4/mm, and its cross-sectional area taken to be 6.77 mm^2/mm.

Before and after each series of tests along a longitudinal line, readings of all gauges were taken without any load on the structure. In most cases these two readings did not have a difference larger than 3×10^{-6} mm/mm. It should be noted that this strain difference is also the measure of the accuracy of the system; this difference corresponds to a surface stress of about 0.6 MPa and, for the plate used in the structure under consideration, it corresponds to a thrust of 4.2 kN/m.

4.1/ Thrusts

Live load thrust values corresponding to the various vehicle positions are shown in Figures 6 through 13. It should be noted that thrusts due to vehicles well away from the strain-gauged section (as, for example, in Figures 7 and 10) are sometimes smaller than the accuracy of the monitoring system. In such cases, the plotted values should be taken to be representing only the pattern of thrusts rather than representing actual values.

As shown in Figure 12, thrusts due to two vehicles, are slightly different than the corresponding sums of thrusts due to two individual vehicles.

4.2/ Moments

In most cases, live load moments were smaller than the accuracy of the measuring system. An idea of the magnitude of moments can be obtained from surface flexural stresses plotted in Figures 14 through 17. It can be seen that even under two 400 kN tandems the maximum flexural stress is less than 2.0 MPa (290 psi).

5/ EFFECT OF THE RELIEVING SLAB

The effect of the relieving slab on live load thrust and moments can be studied by comparing the measured results with those corresponding to another similar structure without a relieving slab. Such a structure has been tested by Bakht [2]. The structure, called the Adelaide Creek soil-steel structure, had an horizontally elliptical conduit with the span and rise of 8.76 m and 4.95 m, respectively. The maximum depth of cover was 1.32 m. This structure has a 17% smaller span than the McIntyre River structure. However, as shown in Figure 18, the span-to-rise ratios, and the ratios of the depth of cover and span, are nearly the same for the two structures. These similarities make the comparison meaningful. It is noted that the Adelaide Creek structure was tested under the same vehicles as those used for the McIntyre River structure, and the procedures for testing were also similar for the two structures. The Adelaide Creek structure is also a Westeel-Roscoe Limited K-D steel pipe, and presumably has a similar backfill as the McIntyre River structure.

Thrusts due to the same vehicle in identical positions, are compared in Figure 6. It can be seen that in spite of a 17% larger span, the structure with the relieving slab has much smaller thrusts that the structure without the slab. The reduction for the maximum thrust is of the order of 50%. Thrusts due to two vehicles are compared in Figure 19. The patterns of thrust distribution around the conduit walls are similar. Here again, the thrust in the structure with the relieving slab is smaller but, in this case, the reduction of the maximum thrust is about 45% as compared to the 50% reduction in the case of single vehicle loading.

The effect of the distance of the live load from the reference section is shown in Figure 20 for maximum thrust. Predictably, in the structure without the relieving slab, the thrust vanishes rapidly with the increase of the distance of the load from the reference section. Attention is drawn to the shape of the thrust-distance curves, one of which is concave and the other convex. For the structure with the relieving slab, the curves become much flatter and their shapes remain concave suggesting a less rapid diminution of thrust.

The zones of influence (i.e., the zone beyond which a live load has negligible influence on thrust in the conduit wall) are shown in Figure 21. The zone of influence for the case without the relieving slab is extrapolated from results of the test on the Adelaide Creek structure. In the longitudinal direction of the conduit the relieving slab extends the zone of influence to its own boundaries, but in the longitudinal direction of the roadway above the zone of influence is surprisingly reduced.

6/ CONCLUSIONS

The comparison of test results on a soil-steel structure with a relieving slab with those on an identical, but smaller, structure without a relieving slab show that the relieving slab has the effect of considerably reducing live load thrusts in the conduit wall. For the structure tested, maximum thrusts were reduced by some 50% due to the introduction of the relieving slab. Live load moments were negligibly small.

ACKNOWLEDGEMENTS

It is acknowledged the test described herein was instigated by Mr M.K. Coyne of Westeel-Roscoe Limited. Permission to test the soil-steel structure was given by Mr R.H. Wright, City Engineer of the Corporation of the City of Thunder Bay; his co-operation and that of his staff during the test is also gratefully acknowledged. The instrumentation of the structure was carried out under the general supervision of Mr J.W. Wagner.

REFERENCES

[1] Bakht, B., and Csagoly, P.F., "Bridge Testing," Structural Research Report SRR-79-10, Research and Development Branch, Ministry of Transportation and Communications, Downsview, Ontario, 1979.

[2] Bakht, B., "Live Load Testing of Soil-Steel Structures," Structural Research Report SRR-80-4, Research and Development Branch, Ministry of Transportation and Communications, Downsview, Ontario.

[3] Bakht, B., "Thrust in Soil-Steel Structures with Relieving Slabs," Report in Preparation.

[4] Fung, C., "Elliptical K-D Steel Pipe for the City of Thunder Bay, Ontario, Design, Instrumentation and Field Testing," Westeel-Roscoe report, 1974.

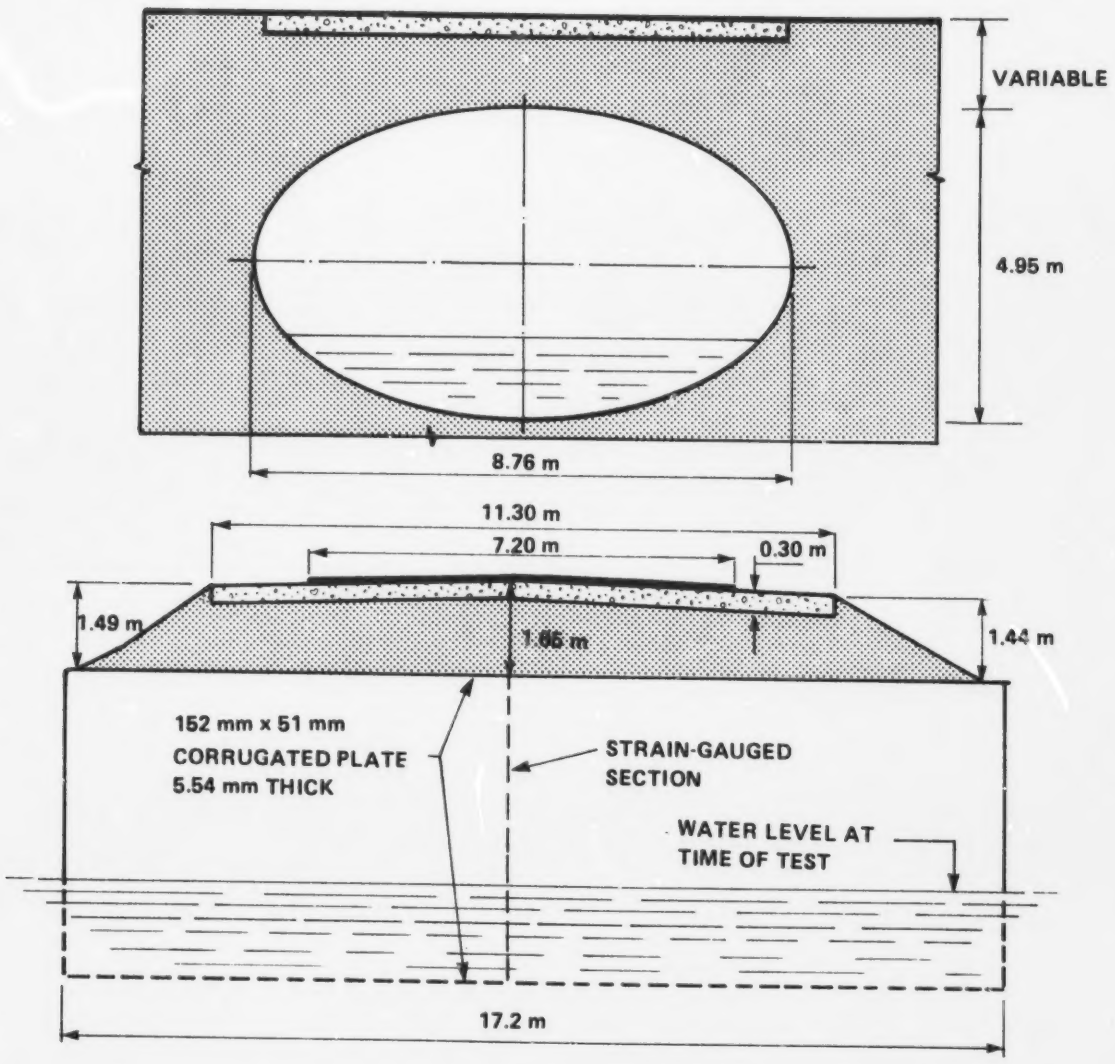


Figure 1/ Details of McIntyre River Soil-Steel Structure

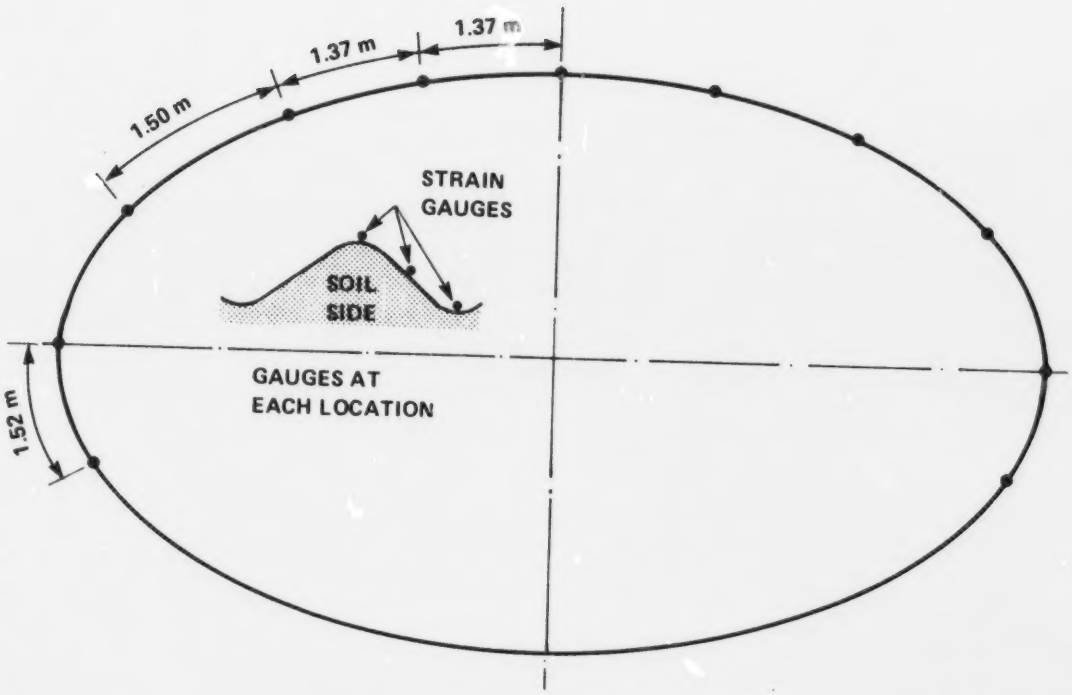


Figure 2/ Strain Gauge Locations

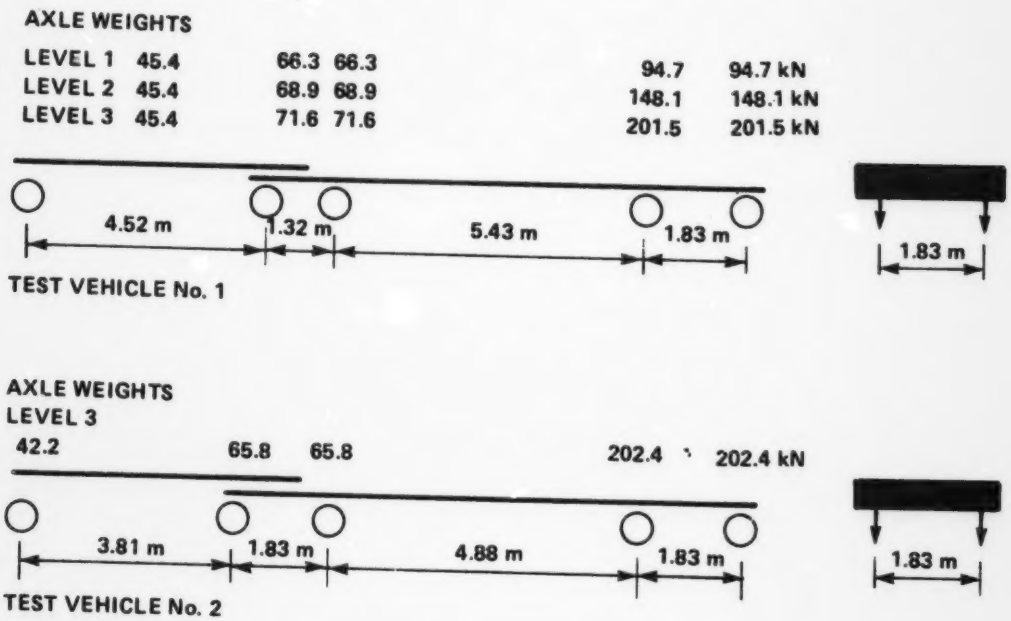


Figure 3/ Details of Test Vehicles

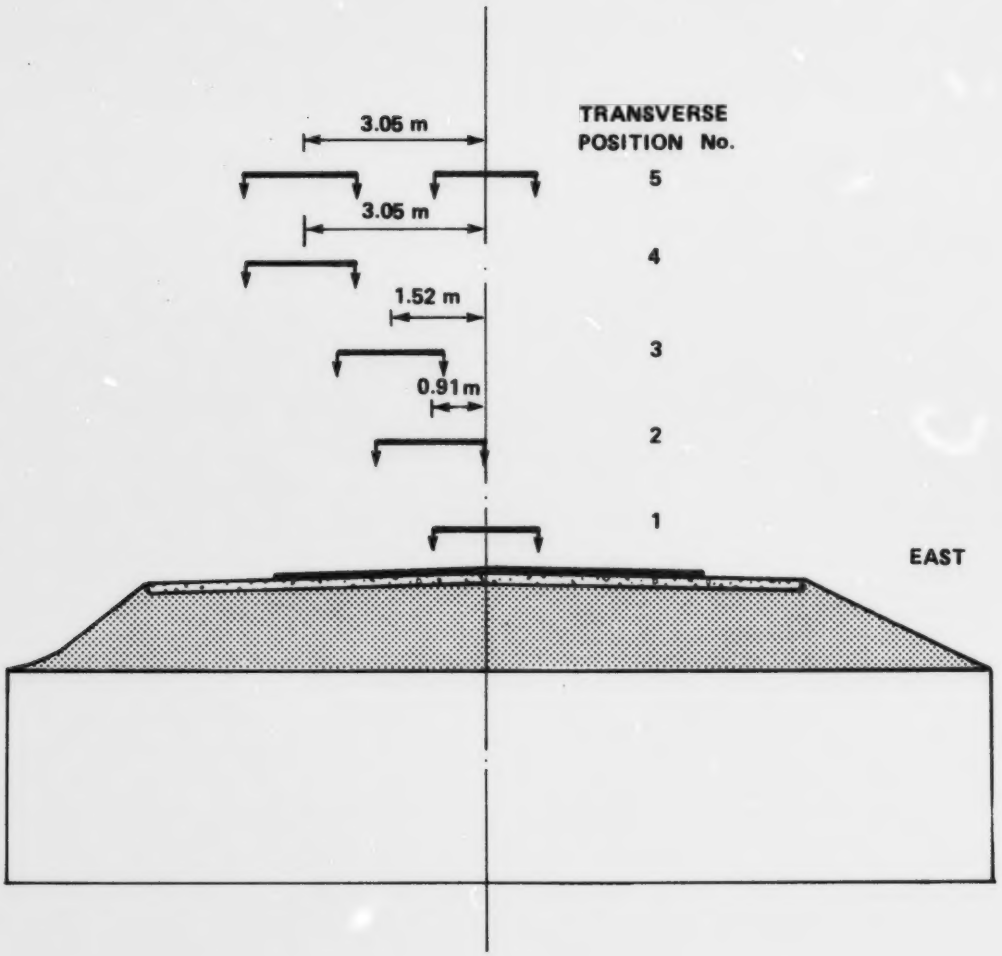


Figure 4/ Transverse Vehicle Positions

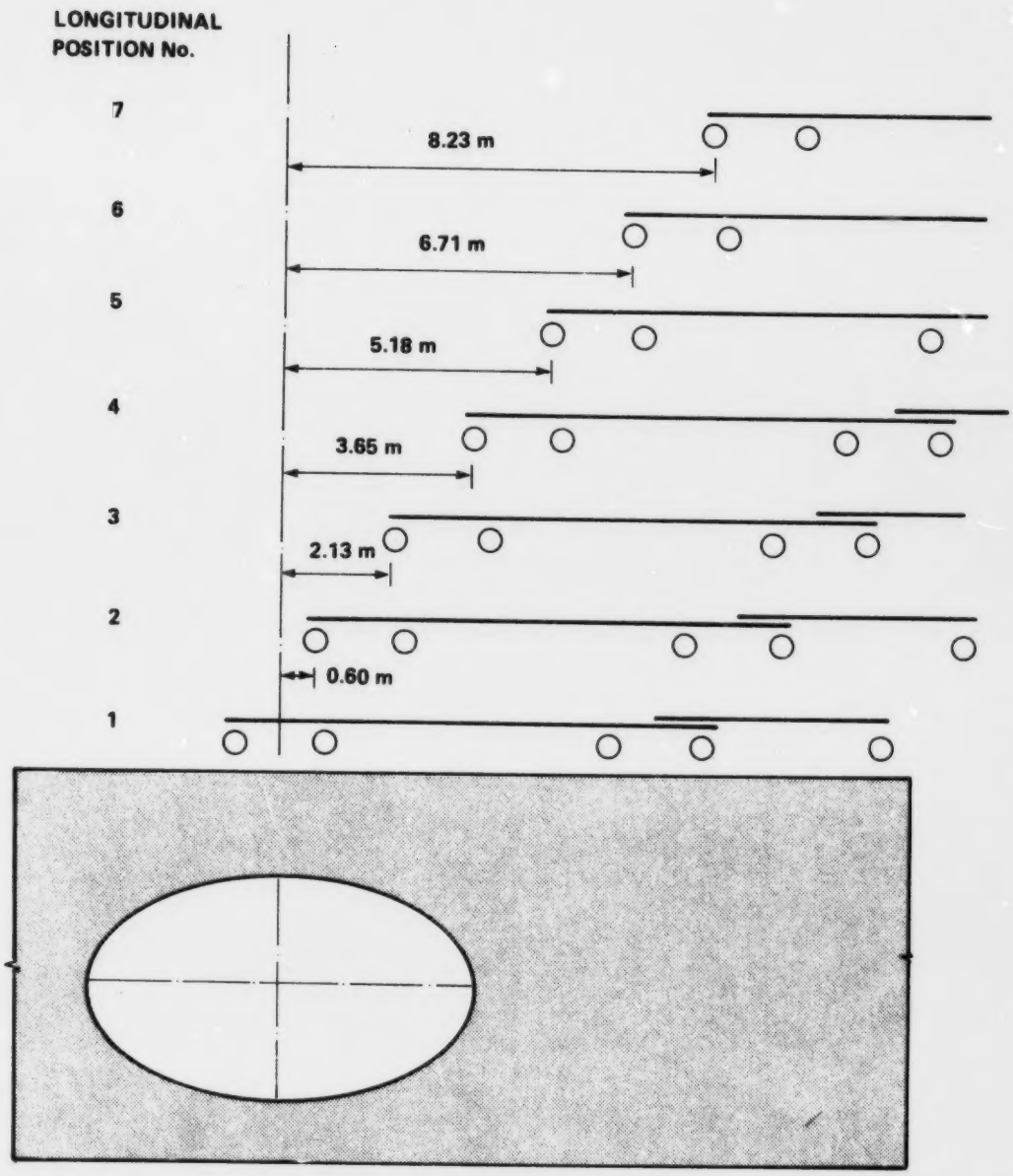


Figure 5/ Longitudinal Vehicle Positions

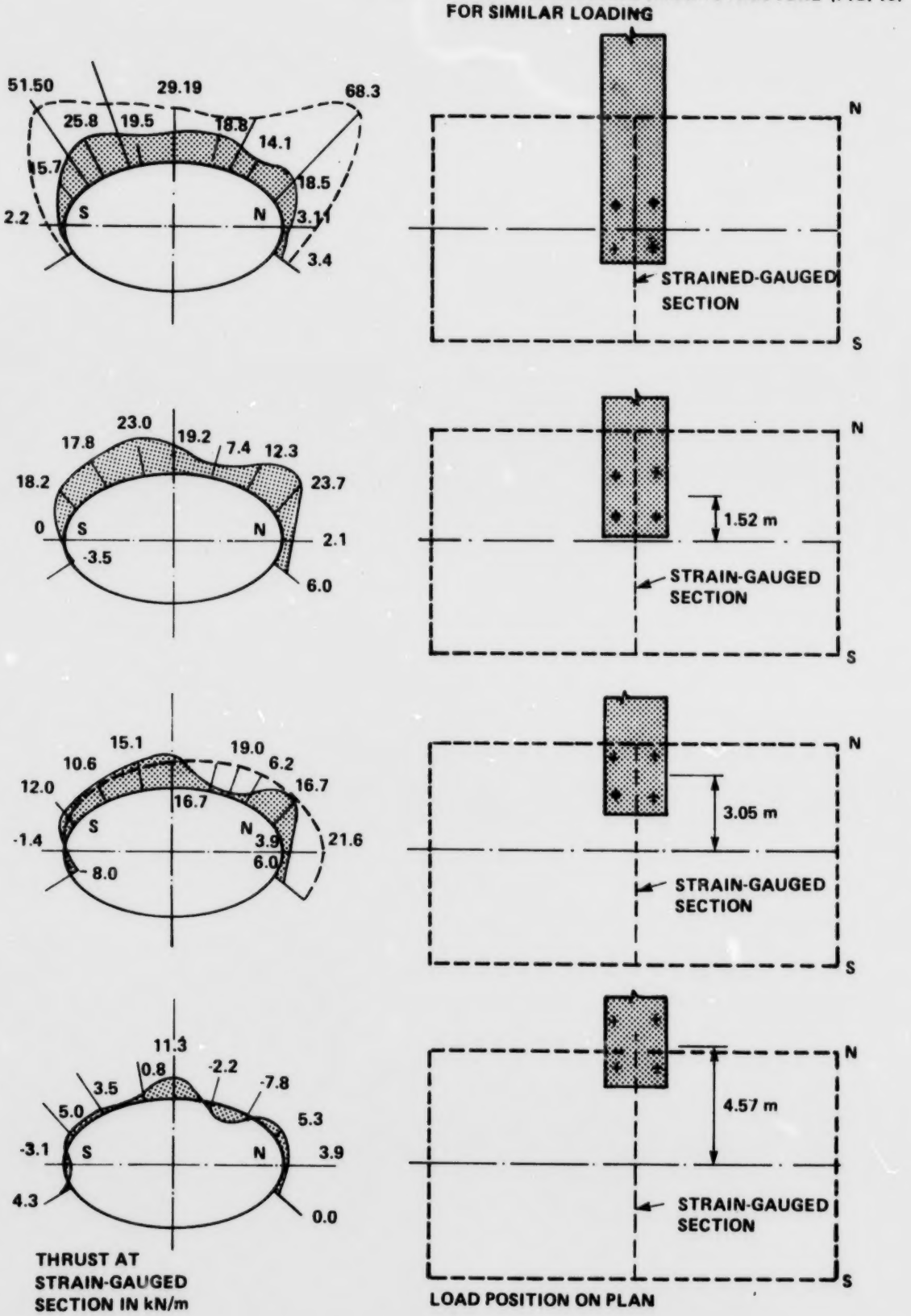


Figure 6/ Thrust in Conduit Wall Due to Test Vehicle No. 1, Load Level 3 (See Figure 3)

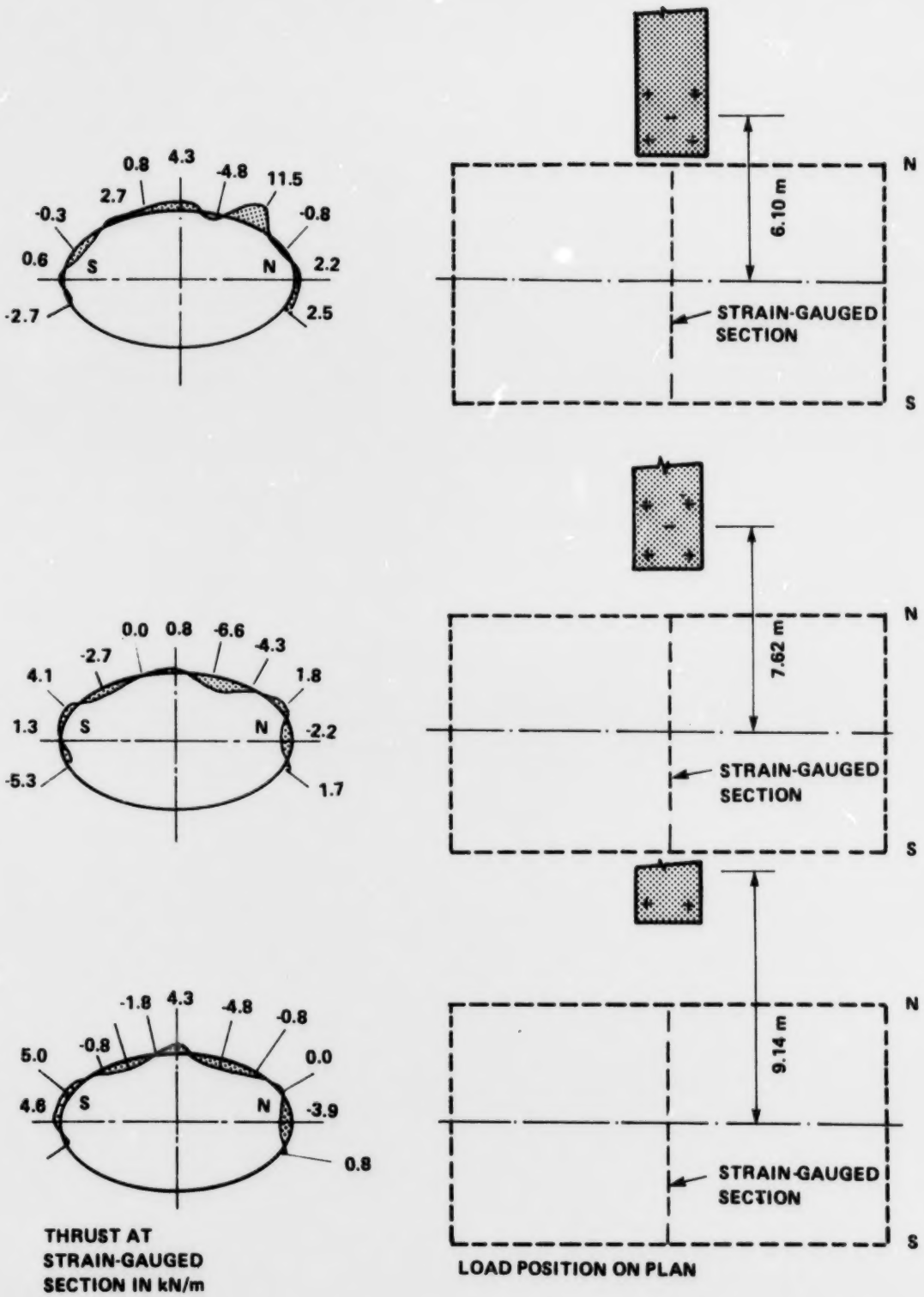


Figure 7/ Thrust in Conduit Wall Due to Test Vehicle No. 1, Load Level 3 (See Figure 3)

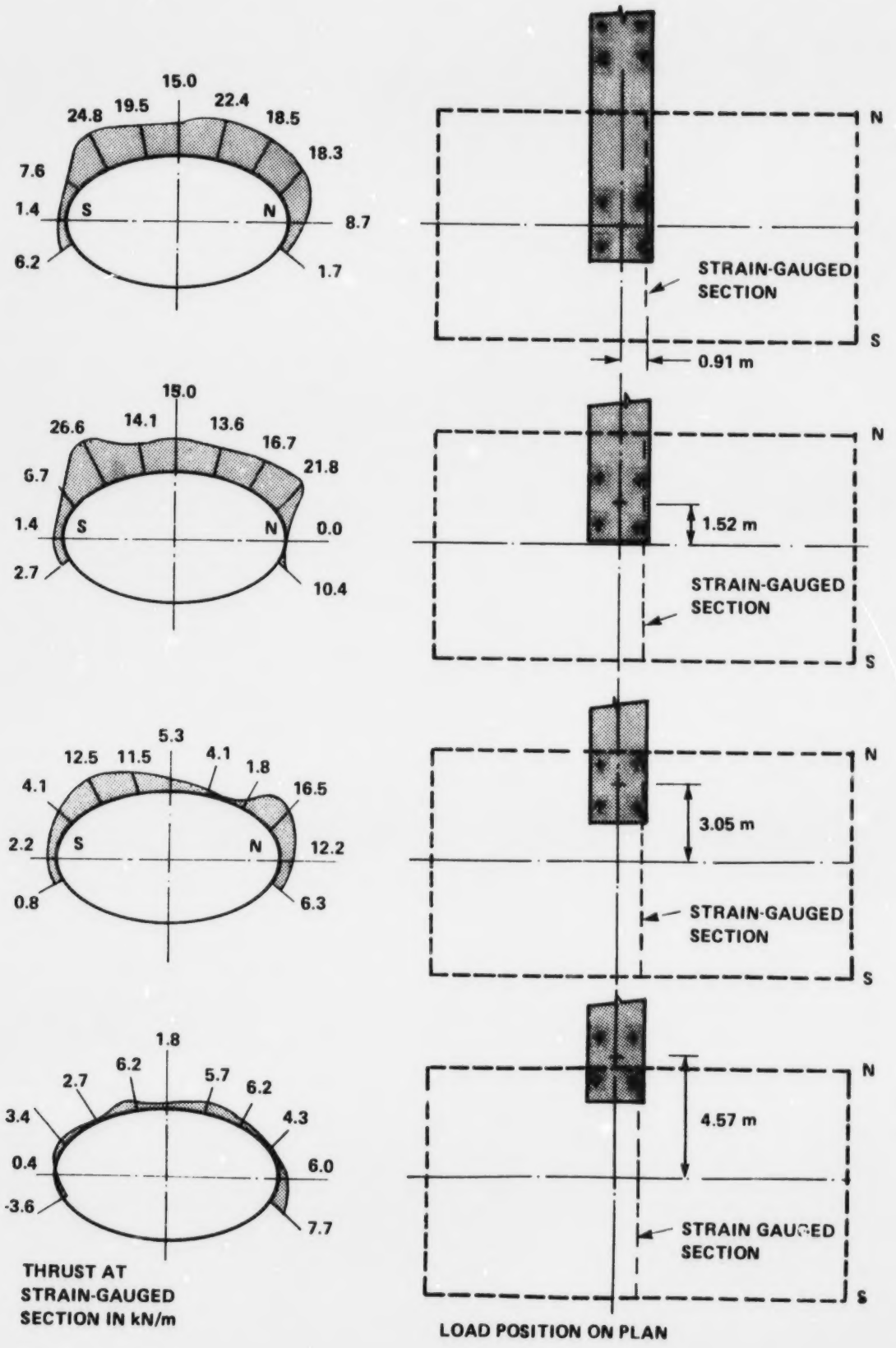


Figure 8/ Thrust in Conduit Wall Due to Test Vehicle No. 1, Load Level 3 (See Figure 3)

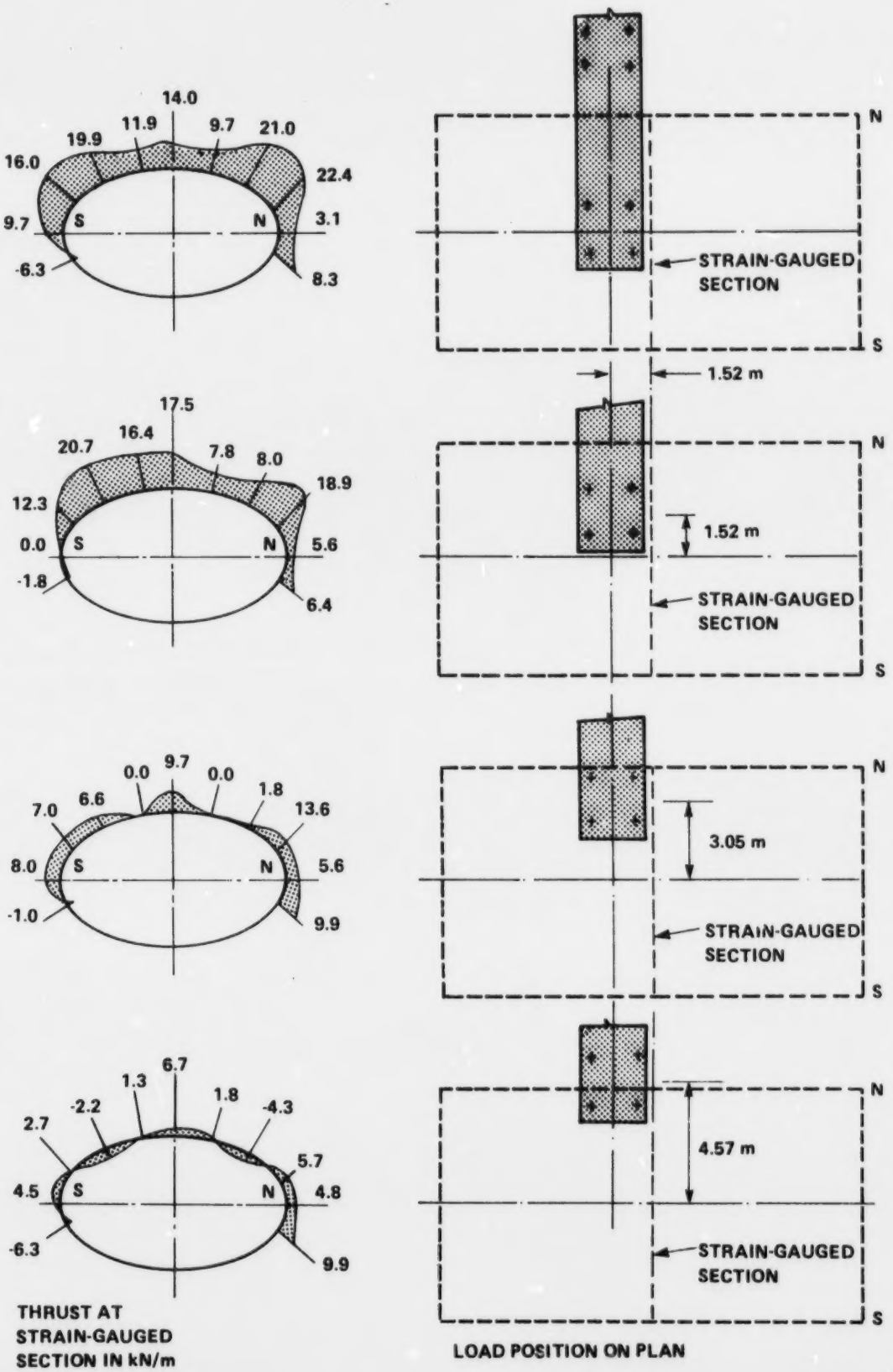


Figure 9/ Thrust in Conduit Wall Due to Test Vehicle No. 1, Load Level 3 (See Figure 3)

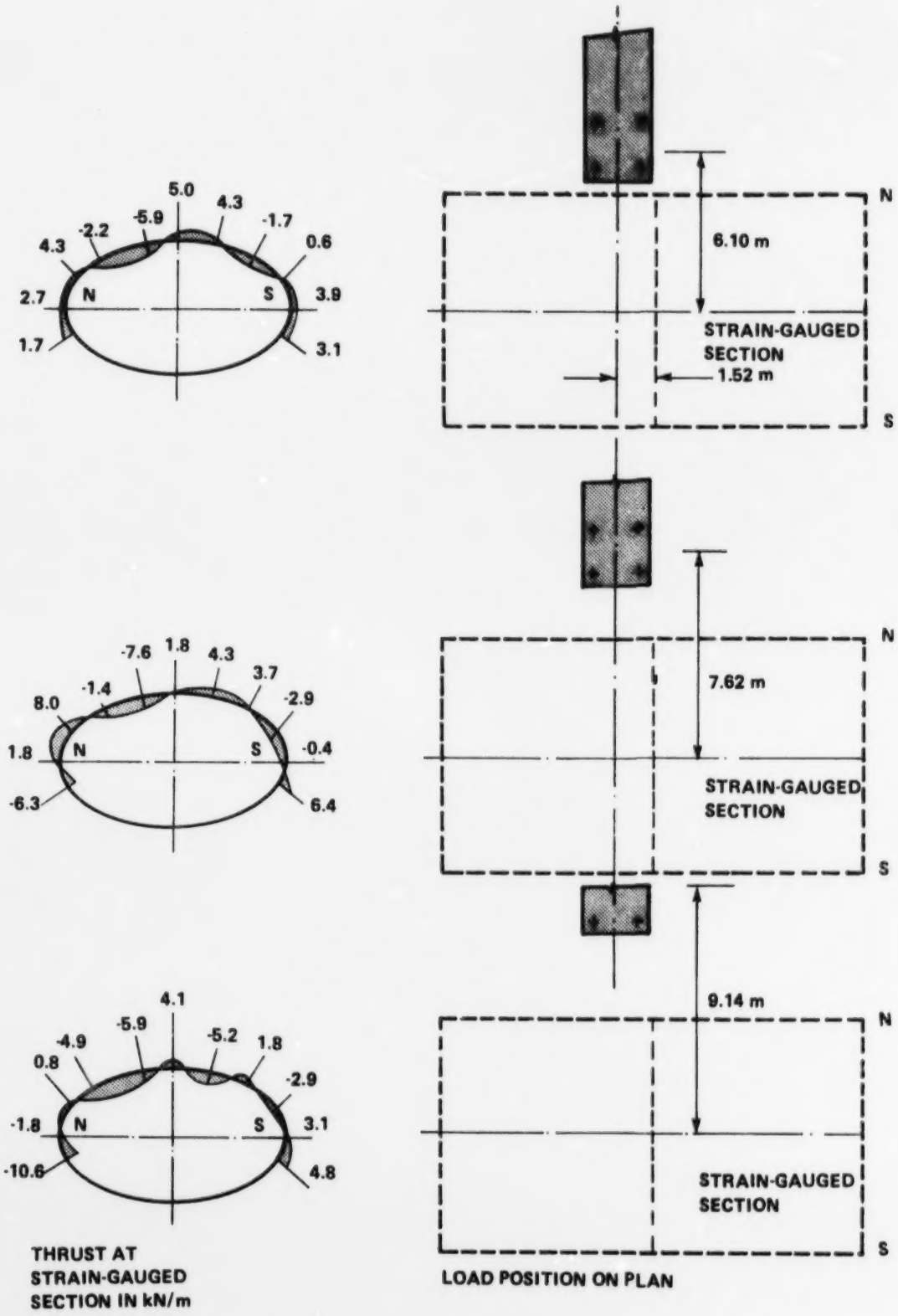


Figure 10/ Thrust in Conduit Wall Due to Test Vehicle No. 1, Load Level 3 (See Figure 3)

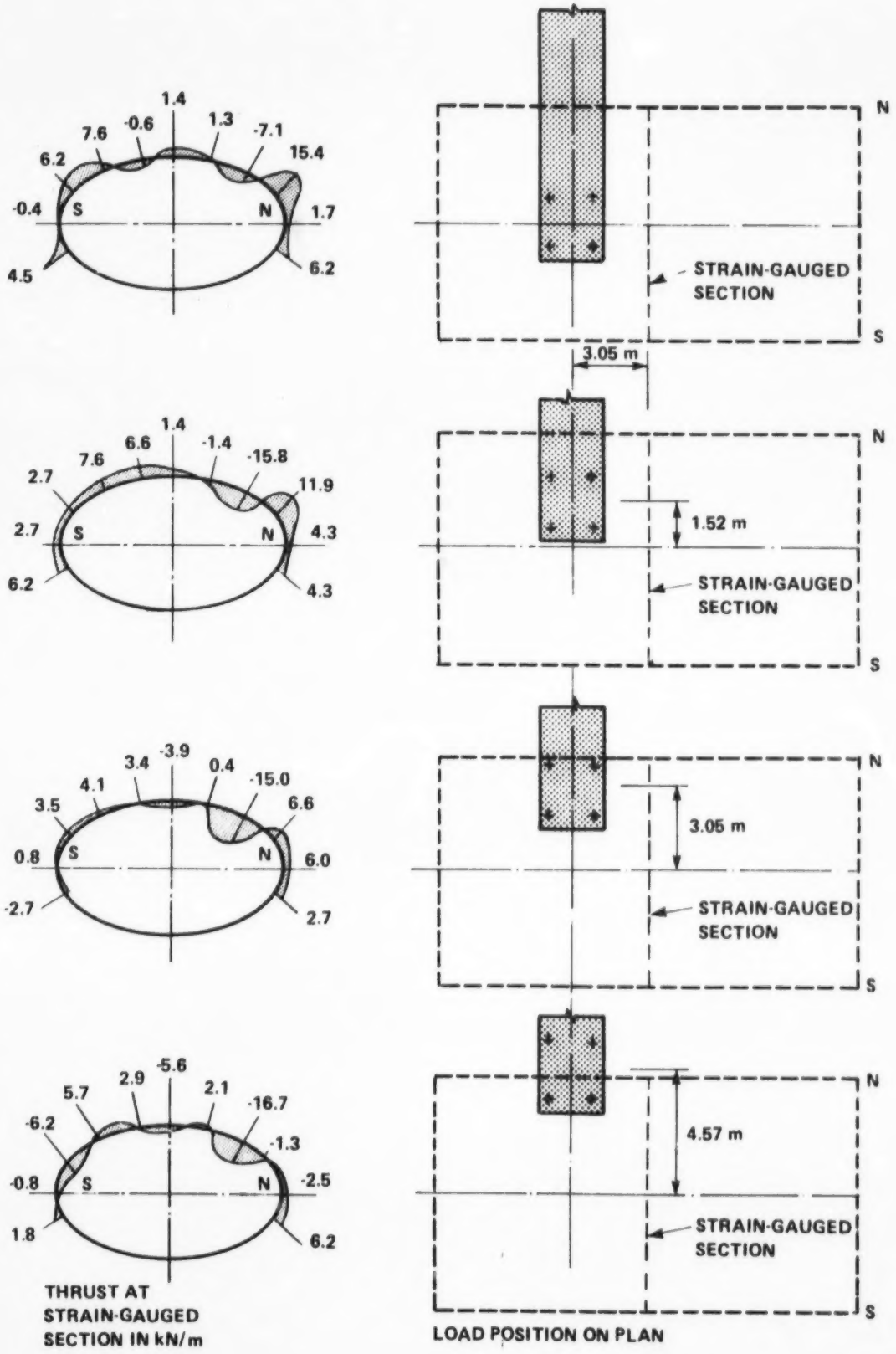


Figure 11/ Thrust in Conduit Wall Due to Test Vehicle No. 1, Level 3 (See Figure 3)

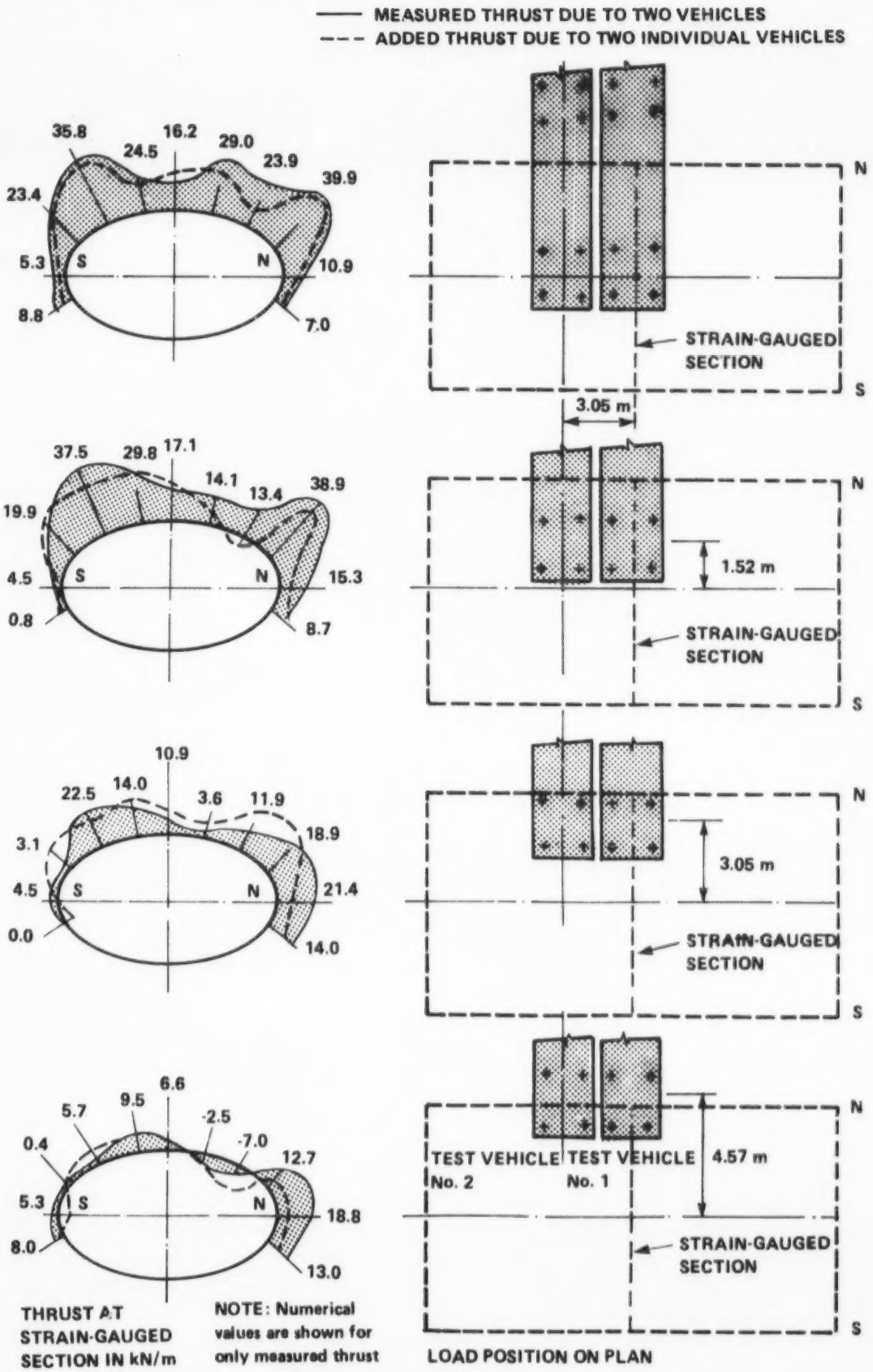


Figure 12/ Thrust in Conduit Wall Due to Two Test Vehicles at Load Level 3 (See Figure 3)

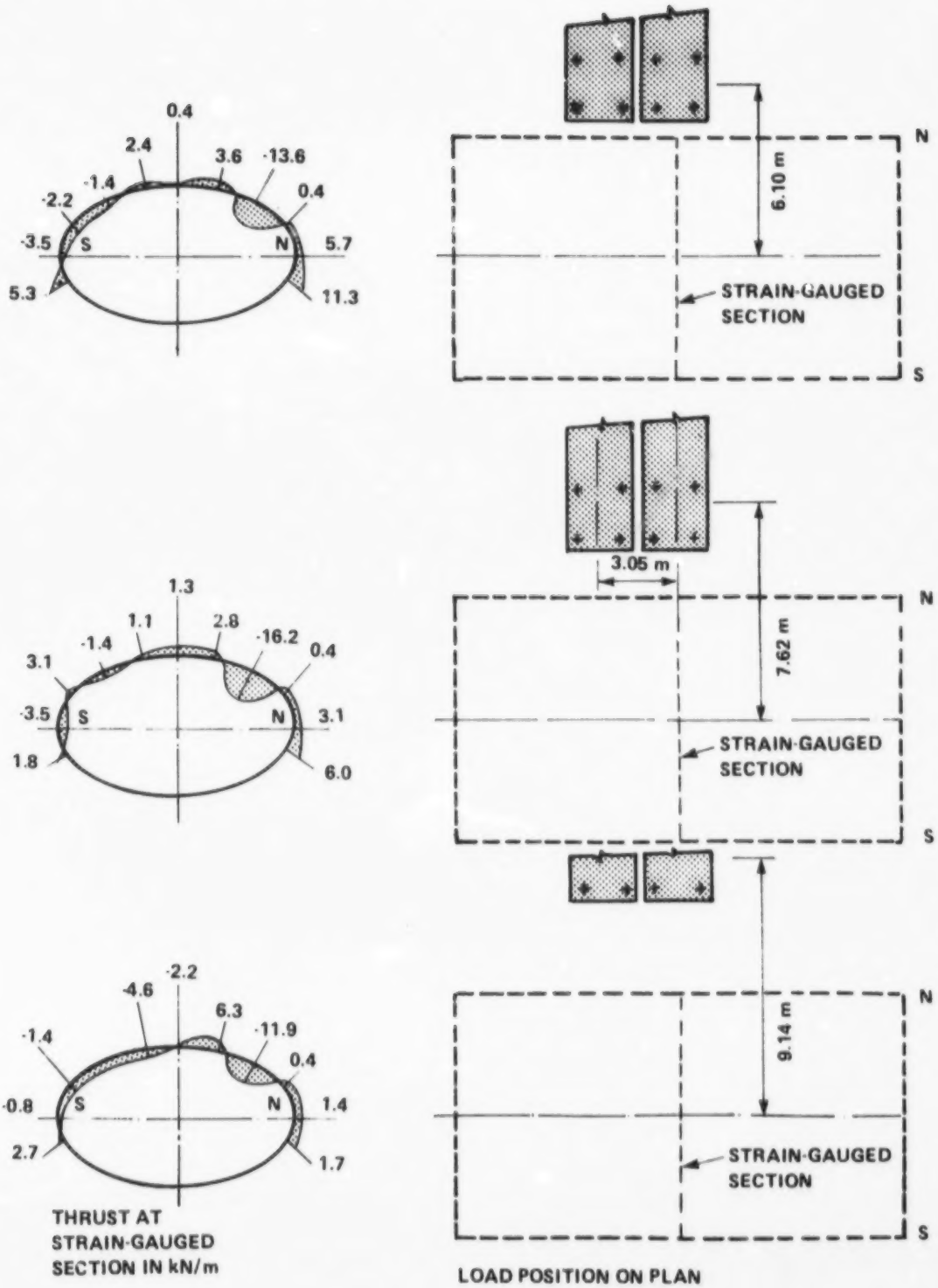


Figure 13/ Thrust in Conduit Wall Due to Two Test Vehicles at Load Level 3 (See Figure 3)

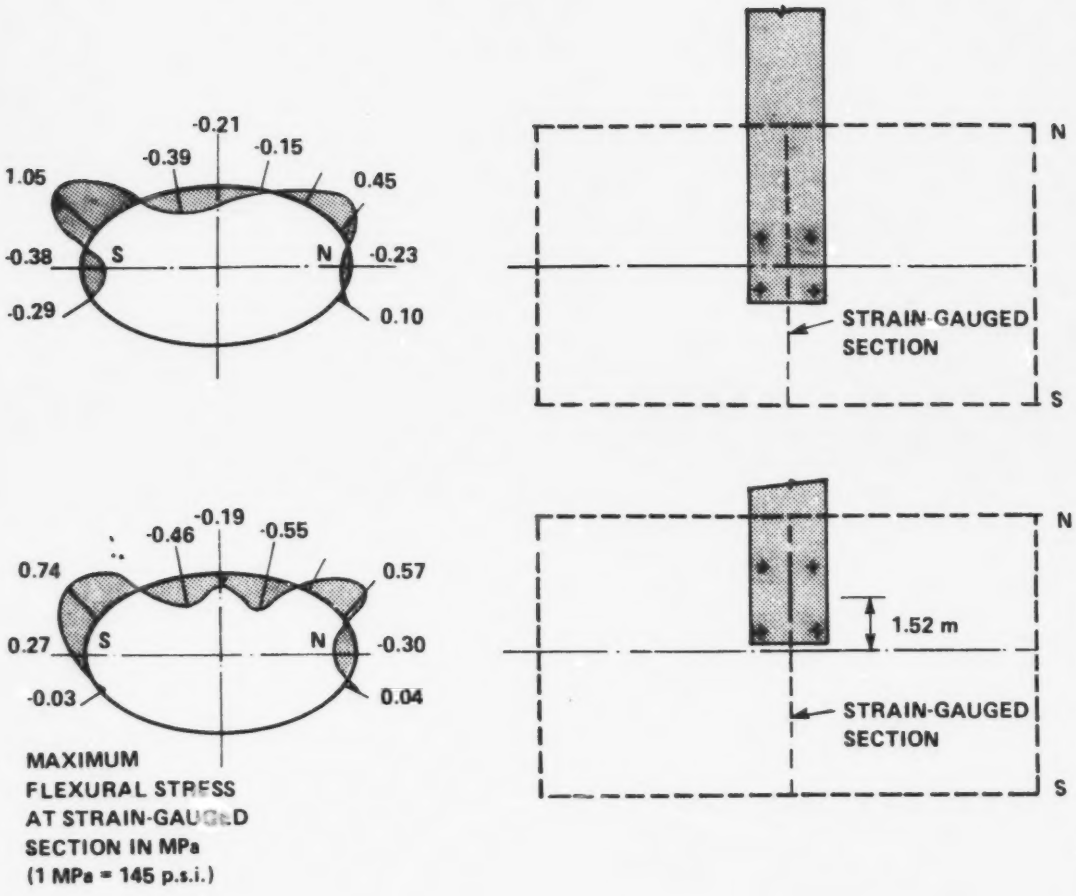


Figure 14/ Flexural Stresses in Conduit Wall Due to Load Level 3 (See Figure 3)

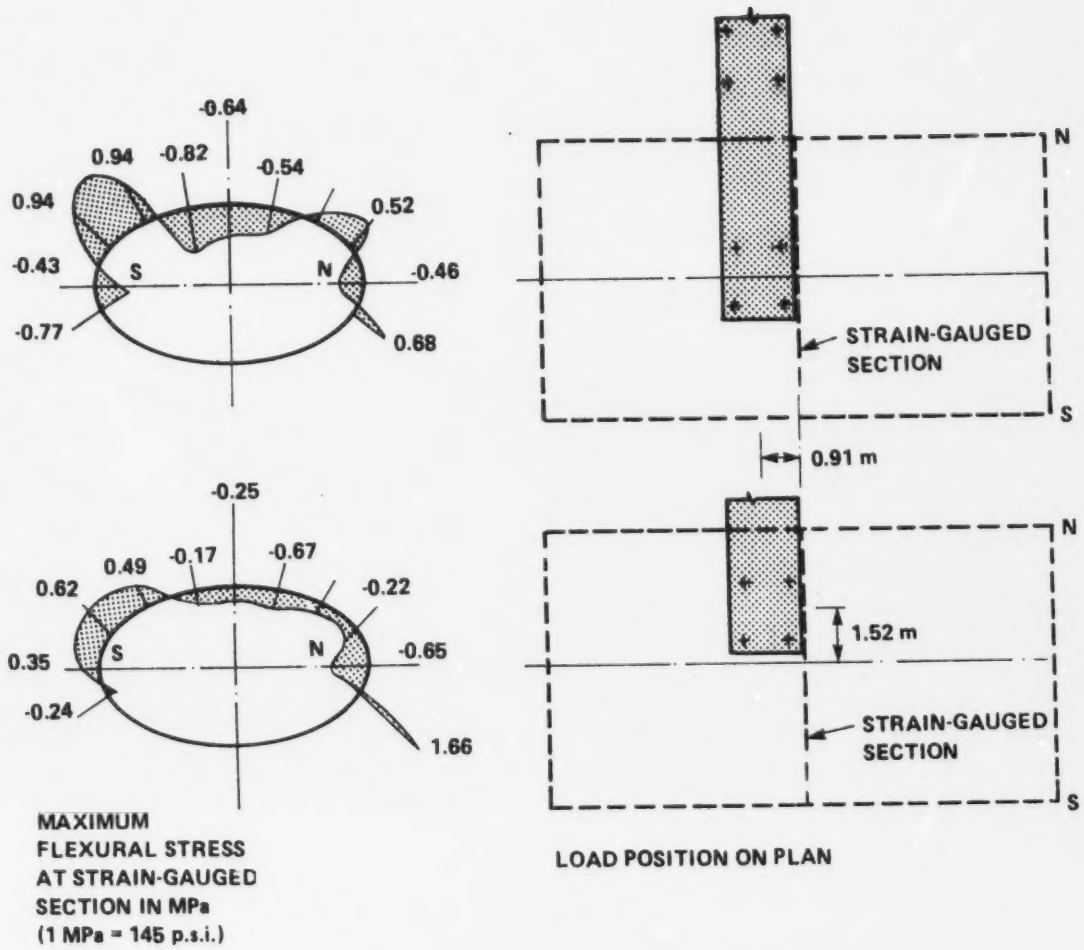


Figure 15/ Flexural Stresses in Conduit Wall Due to Load Level 3 (See Figure 3)

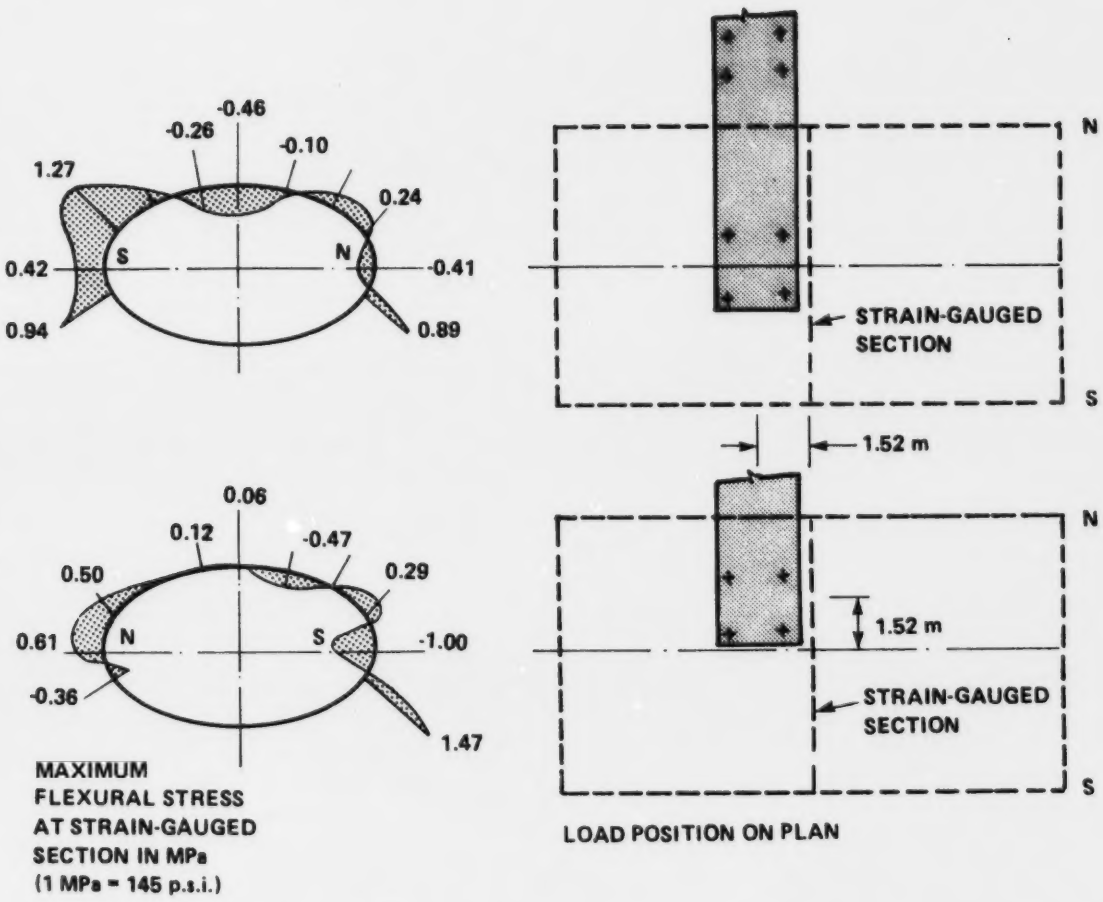


Figure 16/ Flexural Stresses in Conduit Wall Due to Load Level 3 (See Figure 3)

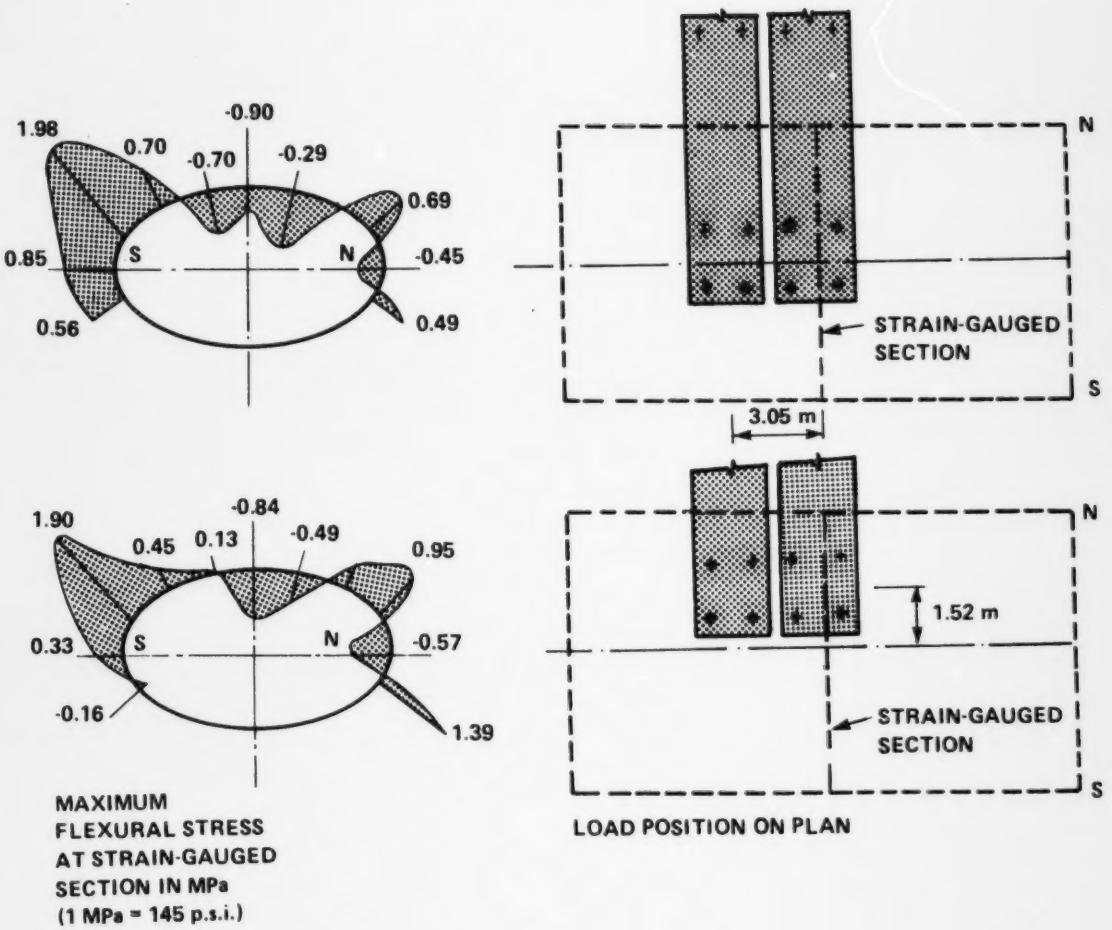
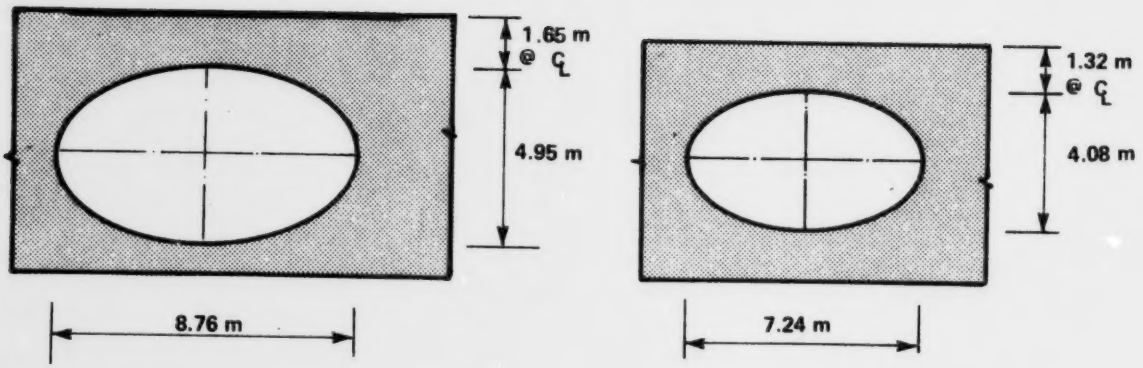


Figure 17/ Flexural Stresses in Conduit Wall Due to Load Level 3 (See Figure 3)



D_H/D_V = 1.77
DEPTH OF COVER/SPAN = 0.188
McINTYRE RIVER STRUCTURE

D_H/D_V = 1.77
DEPTH OF COVER/SPAN = 0.182
ADELAIDE CREEK STRUCTURE

Figure 18/ Comparison of Cross-Sections of McIntyre River and Adelaide Creek Soil-Steel Structures

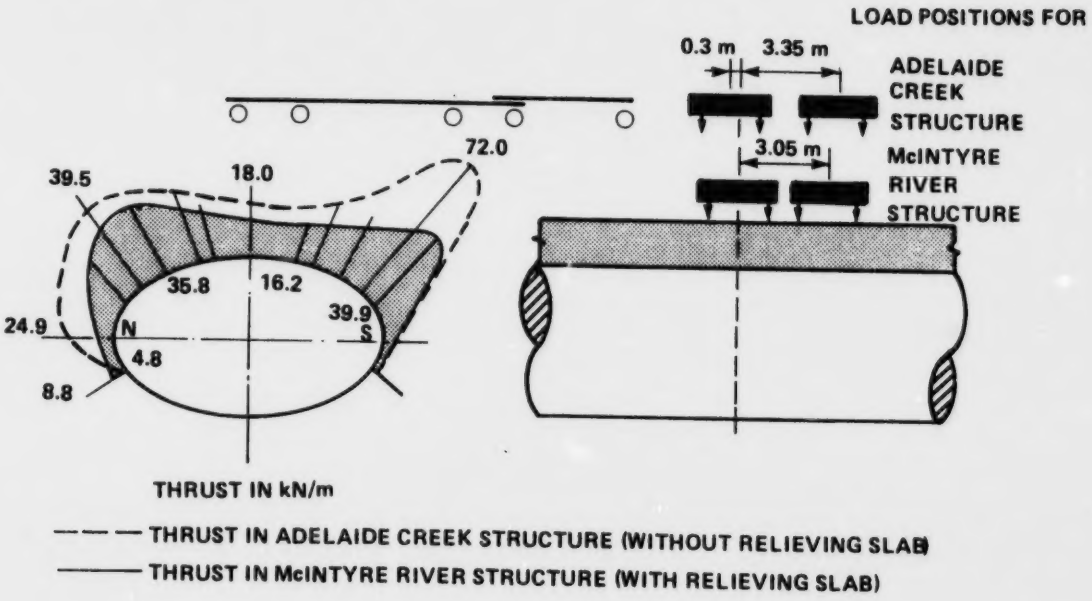
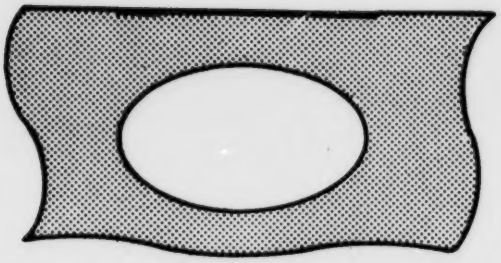
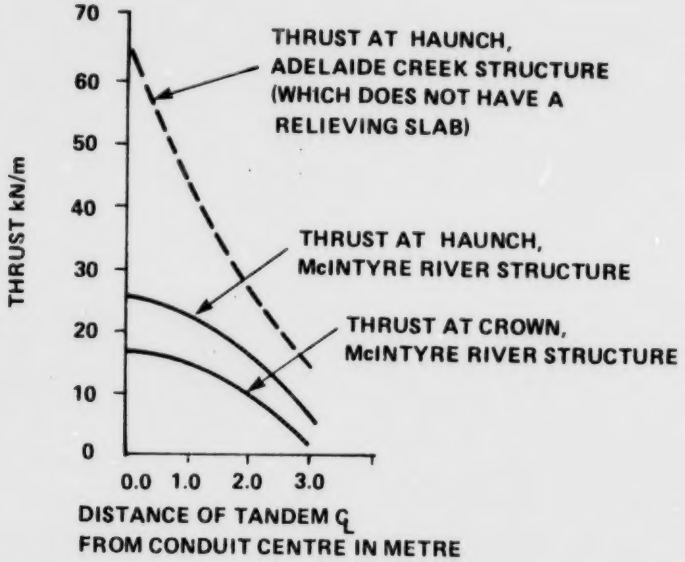
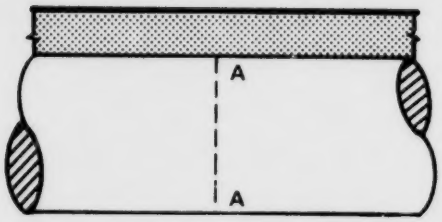


Figure 19/ Effect of Relieving Slab on Thrust Due to Two Vehicles (Load Level 3, Figure 3)







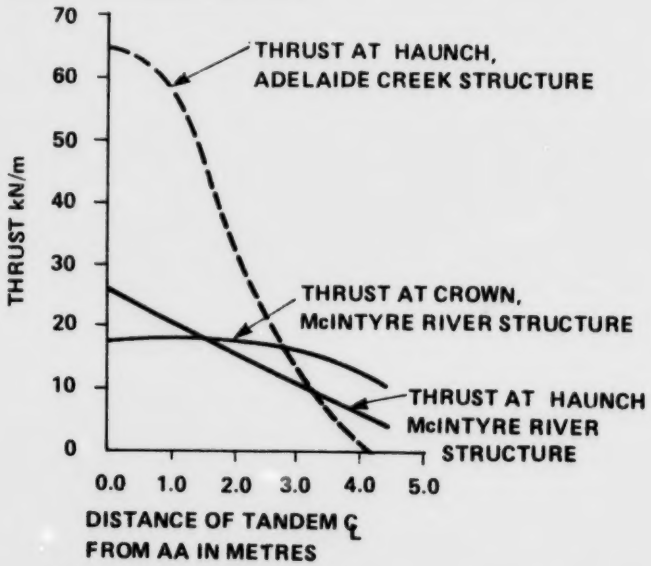


Figure 20/ Effect of Vehicle Position on Thrust

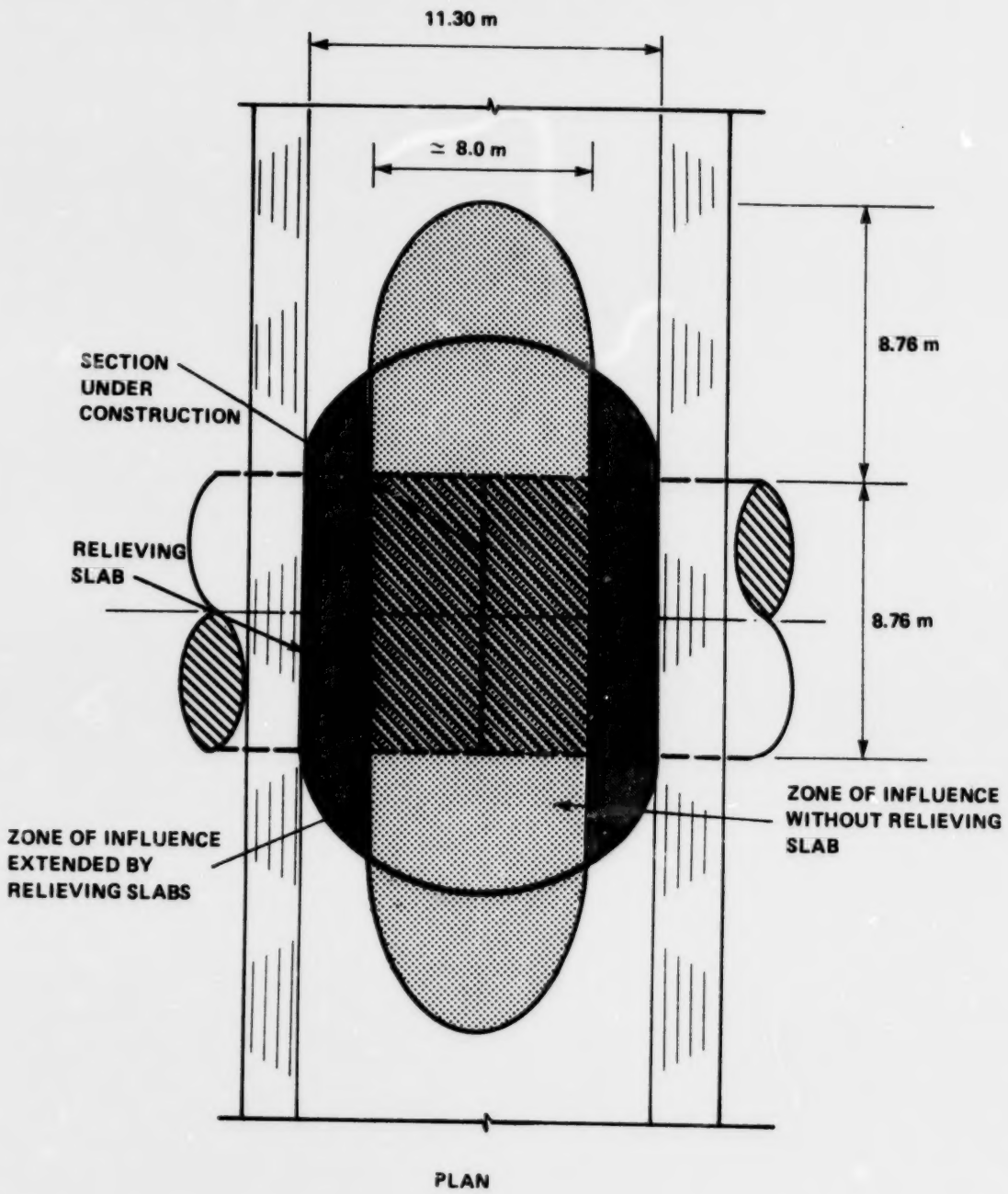


Figure 21/ Zone of Live Load Influence on Thrust

POOR

QUALITY

ORIGINAL